Citation:

Moorhead SA, Welch RW, Barbara M, Livingstone E, McCourt M, Burns AA, Dunne A. The effects of the fibre content and physical structure of carrots on satiety and subsequent intakes when eaten as part of a mixed meal. *Br J Nutr.* 2006; 96(3): 587-595.

PubMed ID: 16925866

Study Design:

Randomized crossover trial

Class:

A - Click here for explanation of classification scheme.

Research Design and Implementation Rating:

POSITIVE: See Research Design and Implementation Criteria Checklist below.

Research Purpose:

To evaluate the effects of the fiber content and physical structure (gross anatomy and cell structure) of carrots on postprandial satiety and subsequent food intakes when consumed as part of a mixed meal.

Inclusion Criteria:

- Females aged 20 to 40 years
- BMI, 20.0 to 29.9kg/m^2
- Non-smokers
- Liking for all the foods to be used in the study
- No known food allergies or restrictions
- Not on a specific diet
- Not taking any medications known to affect appetite
- Not taking oral contraceptives
- Regularly menstruating
- Not pregnant or lactating
- Generally healthy.

Exclusion Criteria:

None specified.

Description of Study Protocol:

Recruitment

Administrative and technical staff at the University of Ulster were recruited.

Design

- Randomized, repeated-measures, within-subject crossover design
- On each occasion, subjects consumed a standardized breakfast that provided 25% of their estimated energy requirement, lunch (the carrot meal) and an afternoon meal eaten ad libitum.

Dietary Intake/Dietary Assessment Methodology

Food was weighed at the ad libitum meal (three hours later), and dietary intake for the remainder of the day was estimated using food diaries.

Intervention

The test lunches (3,329kJ) comprised boiled rice (200g) with sweet and sour sauce (200g) that included chicken (200g) and carrots (200g) in three conditions:

- Whole carrots (fiber and structure)
- Blended carrots (fiber but no structure)
- Carrot nutrients (no fiber or structure).

All meals had the same energy, macronutrient, Na, K, Ca and water contents, and the same weight and volume.

Statistical Analysis

- ANOVA was performed with a mixed-effect model for a three-period cross-over design, which compared the three conditions (whole carrots, blended carrots, carrot nutrients). The model contained condition, period and 'carry-over', a random subject effect and a random error. As stated, subjects were treated as random, and the fixed effects were condition, period and 'carry-over'
- The condition effect refers to differences in the mean response of the variables (VAS and timings, and the weight of food and drink, energy, macronutrient, fiber, water and alcohol intakes) between the three conditions, whereas the period effect refers to differences in the mean responses due to systematic differences between the treatment periods
- Analysis showed that the effects of carry-over and period were non-significant (NS). Thus, assuming no carry-over, an F-ratio test was conducted for the comparison of significant effects of each variable between conditions
- To compare specific conditions, linear contrasts were used to examine differences between means. Results were considered significant at $P<0.05$.

Data Collection Summary:

Timing of Measurements

- Each participant was studied on three occasions on the same day of the week with a four-week interval between crossover to minimize potential effects of the menstrual cycle
- Participants fasted from 22.00 hours the previous day and arrived at 9.00 hours in a fasting state
- On arrival, compliance was confirmed, and the subjects consumed breakfast and left the

metabolic suite
- Subjects returned at 12.30 hours, and completed the VAS, after which lunch was served and time-to-eat was covertly recorded
- After lunch, the subjects completed the VAS and left the metabolic suite with instructions to complete the VAS every 45 minutes until the afternoon meal (16.00 hours)
- Subjects returned to the metabolic suite at 16.00 hours, completed their final VAS and were provided with an afternoon meal eaten ad libitum
- After this, subjects were given food diaries to complete (description of food, brand name if appropriate, estimated portions and leftovers) for the remainder of the day.

Dependent Variables

- Food intake (ad libitum afternoon meal by weighing and remainder of the day by food diary)
- Postprandial satiety by visual analogue scales (VAS).

Independent Variables

Carrot form:

- Whole carrots suspended in sauce
- Blended carrots in sauce
- Carrot nutrients in sauce (formulated from food ingredients to give the same energy, major nutrients and portion weight as the whole or blended carrots).

Control Variables

- Subjects gave the date of the start of their last menstruation, and were assigned to six groups of six persons each so that subjects were at similar points in their menstrual cycle on each study day (i.e., days 4 to 10, when food intake is reportedly most stable)
- Subjects were asked not to eat or drink anything except the food and beverages provided until after the afternoon meal and to refrain from strenuous physical activity.

Description of Actual Data Sample:

- *Initial N:* 36 women
- *Attrition (final N):* Four participants withdrew during study
  - Whole carrots: N=34
  - Blended carrots: N=34
  - Carrot nutrients: N=32
- *Age:* 33 (7.03) years (range 21 to 40 years)
- *Anthropometrics:* BMI=24.4 (4.03) kg/m^2 (range 20.9 to 28.7kg/m^2)
- *Location:* United Kingdom.

Summary of Results:

Key Findings

- All subjects consumed the complete lunch meal
- Subjects reported feeling significantly less hungry, more full, with lower desire to eat and prospective consumption after consuming the meals with whole and blended carrots compared with the meal with carrot nutrients. Differences in the satiety ratings between the

whole and blended carrots were NS

- Intakes of energy, food, drink, macronutrients, fiber and water at the afternoon meal eaten ad libitum (three hours after the lunch meal) decreased consistently in the order carrot nutrients more than blended carrots more than whole carrots. There were significant differences between the three conditions for intakes of total energy, food energy, carbohydrate and protein. Notably, at the meal eaten ad libitum, compared with the carrot nutrient condition, total energy intakes were 634kJ (22 %) lower following the blended carrots and 1,212kJ (42%) lower following the whole carrots
- Reported food, drink, energy, macronutrient, fiber, water and alcohol intakes for the remainder of the day showed a similar general pattern to those found at the afternoon meal eaten ad libitum, with intakes decreasing consistently in the order carrot nutrients more than blended carrots more than whole carrots. These differences were significant only for intakes of weight of food, total energy, food energy, carbohydrate and fat, which were significantly lower for the whole and blended carrots compared with the carrot nutrient condition, and for protein, which was significantly lower for the whole carrots compared with the other two conditions.

Total Energy Intakes (kJ)

Variable	Whole Carrots (N=34)	Blended Carrots (N-34)	Carrot Nutrients (N=32)
Afternoon ad libitum meal	1,669[a] (489)	2,247[b] (904)	2,881[c] (778)
Remainder of the day	756[a] (323)	1,021[a] (327)	1,551[b] (446)

Mean values within a row with unlike superscript letters were significantly different ($P<0.05$, F-ratio test).

Author Conclusion:

This study has shown that whole or blended carrots, eaten as part of a mixed lunch meal, result in significantly increased satiety and decreased subsequent intakes.

Reviewer Comments:

Research Design and Implementation Criteria Checklist: Primary Research

Relevance Questions

1.	Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (Not Applicable for some epidemiological studies)	Yes
2.	Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about?	Yes

3.	Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to nutrition or dietetics practice?	Yes
4.	Is the intervention or procedure feasible? (NA for some epidemiological studies)	Yes

Validity Questions

1.	**Was the research question clearly stated?**	Yes
1.1.	Was (were) the specific intervention(s) or procedure(s) [independent variable(s)] identified?	Yes
1.2.	Was (were) the outcome(s) [dependent variable(s)] clearly indicated?	Yes
1.3.	Were the target population and setting specified?	Yes
2.	**Was the selection of study subjects/patients free from bias?**	Yes
2.1.	Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?	Yes
2.2.	Were criteria applied equally to all study groups?	Yes
2.3.	Were health, demographics, and other characteristics of subjects described?	Yes
2.4.	Were the subjects/patients a representative sample of the relevant population?	???
3.	**Were study groups comparable?**	Yes
3.1.	Was the method of assigning subjects/patients to groups described and unbiased? (Method of randomization identified if RCT)	Yes
3.2.	Were distribution of disease status, prognostic factors, and other factors (e.g., demographics) similar across study groups at baseline?	Yes
3.3.	Were concurrent controls used? (Concurrent preferred over historical controls.)	Yes
3.4.	If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?	N/A
3.5.	If case control or cross-sectional study, were potential confounding factors comparable for cases and controls? (If case series or trial with subjects serving as own control, this criterion is not applicable. Criterion may not be applicable in some cross-sectional studies.)	N/A

3.6.	If diagnostic test, was there an independent blind comparison with an appropriate reference standard (e.g., "gold standard")?	N/A
4.	**Was method of handling withdrawals described?**	Yes
4.1.	Were follow-up methods described and the same for all groups?	???
4.2.	Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)	Yes
4.3.	Were all enrolled subjects/patients (in the original sample) accounted for?	Yes
4.4.	Were reasons for withdrawals similar across groups?	Yes
4.5.	If diagnostic test, was decision to perform reference test not dependent on results of test under study?	N/A
5.	**Was blinding used to prevent introduction of bias?**	???
5.1.	In intervention study, were subjects, clinicians/practitioners, and investigators blinded to treatment group, as appropriate?	No
5.2.	Were data collectors blinded for outcomes assessment? (If outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)	???
5.3.	In cohort study or cross-sectional study, were measurements of outcomes and risk factors blinded?	N/A
5.4.	In case control study, was case definition explicit and case ascertainment not influenced by exposure status?	N/A
5.5.	In diagnostic study, were test results blinded to patient history and other test results?	N/A
6.	**Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were interveningfactors described?**	Yes
6.1.	In RCT or other intervention trial, were protocols described for all regimens studied?	Yes
6.2.	In observational study, were interventions, study settings, and clinicians/provider described?	Yes
6.3.	Was the intensity and duration of the intervention or exposure factor sufficient to produce a meaningful effect?	Yes
6.4.	Was the amount of exposure and, if relevant, subject/patient compliance measured?	Yes
6.5.	Were co-interventions (e.g., ancillary treatments, other therapies) described?	Yes
6.6.	Were extra or unplanned treatments described?	N/A

6.7.	Was the information for 6.4, 6.5, and 6.6 assessed the same way for all groups?	Yes
6.8.	In diagnostic study, were details of test administration and replication sufficient?	N/A
7.	**Were outcomes clearly defined and the measurements valid and reliable?**	Yes
7.1.	Were primary and secondary endpoints described and relevant to the question?	Yes
7.2.	Were nutrition measures appropriate to question and outcomes of concern?	Yes
7.3.	Was the period of follow-up long enough for important outcome(s) to occur?	Yes
7.4.	Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?	Yes
7.5.	Was the measurement of effect at an appropriate level of precision?	Yes
7.6.	Were other factors accounted for (measured) that could affect outcomes?	Yes
7.7.	Were the measurements conducted consistently across groups?	Yes
8.	**Was the statistical analysis appropriate for the study design and type of outcome indicators?**	Yes
8.1.	Were statistical analyses adequately described and the results reported appropriately?	Yes
8.2.	Were correct statistical tests used and assumptions of test not violated?	Yes
8.3.	Were statistics reported with levels of significance and/or confidence intervals?	Yes
8.4.	Was "intent to treat" analysis of outcomes done (and as appropriate, was there an analysis of outcomes for those maximally exposed or a dose-response analysis)?	Yes
8.5.	Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?	Yes
8.6.	Was clinical significance as well as statistical significance reported?	Yes
8.7.	If negative findings, was a power calculation reported to address type 2 error?	N/A
9.	**Are conclusions supported by results with biases and limitations taken into consideration?**	Yes
9.1.	Is there a discussion of findings?	Yes
9.2.	Are biases and study limitations identified and discussed?	Yes
10.	**Is bias due to study's funding or sponsorship unlikely?**	Yes

10.1.	Were sources of funding and investigators' affiliations described?	Yes
10.2.	Was the study free from apparent conflict of interest?	Yes